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REPORT:

Final Technical Report

GRANT:

NAGW-1475

- a) Accurate Ground-Based Calibration of HRS/HST
Absolute Wavelengths
- b) Ground-Based Studies of Interstellar Absorption

INSTITUTION:

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This Final Technical Report is submitted in accordance with the Provisions for Research Grants. During the performance period, the work supported by this grant was reported in the following papers published in refereed scientific journals:

- 1) D. E. Welty, L. M. Hobbs, L. Blitz, and B. E. Penprase, "On the Nearest Molecular Clouds. III. MBM 40, 53, 54, and 55", *ApJ*, 346, 232 (1989)
- 2) L. M. Hobbs and D. E. Welty, "The Interstellar D₁ Line at High Resolution", *ApJ*, 368, 426 (1991)
- 3) L. M. Hobbs, R. Ferlet, D. E. Welty, and G. Wallerstein, "Variable Interstellar Absorption toward HD 72127 A. II. 1981 - 1988", *ApJ*, 378, 586 (1991)
- 4) D. E. Welty, L. M. Hobbs, and V. Kulkarni, "A High-Resolution Survey of Interstellar Na I D₁ Lines", *ApJ*, 436, 152 (1994)

Two additional observing programs are still in progress but are nearing completion. Entirely supported so far by the present grant, the first consists of high resolution observations of the interstellar K I 7699 Å line in the spectra of about 15 stars; these data are of a quality entirely comparable to the better profiles found in papers 2 and 4 above. These results will probably be ready to submit for publication in early 1996. Partially supported by the present grant, the second program consists of high-resolution observations of the interstellar Ca II K line in the spectra of 44 stars, including data obtained at a velocity resolution of about 0.3 km s^{-1} for 13 of these stars. The results will be reported in the following paper, which should be submitted within the month:

- 5) D. E. Welty, D. C. Morton, and L. M. Hobbs, "A High-Resolution Survey of Interstellar Ca II Absorption", *ApJ* (to be submitted).

The observations supported by this award were carried out in order to achieve simultaneously two related, primary goals. The first, purely scientific purpose was to advance significantly our understanding of the interstellar gas, by using state-of-the-art instrumental capabilities to measure the profiles of a relatively large number of interstellar absorption lines with unprecedentedly high spectral resolution, along with a suitably high S/N ratio. A specific goal, which was fully realized in practice, was to detect the resolved hyperfine structure (hfs) components of a significant number of interstellar Na I D₁ lines. Observational data of such high quality permitted us to establish a much more complete census of the distinct interstellar clouds along the respective light paths than before, and also to obtain stringent, rigorous upper limits on the temperatures and the internal motions of the respective individual clouds, from the measured widths of the hfs components. There is effectively no other method currently available for acquiring these kinds of fundamental information. The detailed results for 276 interstellar clouds identified along the light paths to 38 stars are summarized in papers 2 and 4 listed above.

The second primary purpose of this observational program was to allow more reliable and comprehensive future analyses of the interstellar lines found in HST/GHRS spectra of these 38 stars; this grant was explicitly awarded, in part, in support of the HST mission. The first important point here is that even the best spectral resolution provided by the GHRS echelle grating is poorer by nearly a factor of ten than that used in these ground-based high-resolution studies of Na I, K I, and Ca II. As a result, as many as four (or more) spatially distinct interstellar clouds, typically with respectively quite different physical properties, are unresolved in GHRS spectra; in the GHRS spectra alone, the distinct clouds are indistinguishable and therefore cannot be analyzed as the disparate, separate entities which they are. However, for each of the 38 stars observed in our ground-based program, a detailed empirical, kinematical model of the genuinely full array of the individual, resolved absorbing clouds along a given light path can be derived from the Na I/K I/Ca II data. This multi-cloud model can then be applied immediately to analyses of the unresolved UV absorption lines of many diagnostically powerful atoms and ions, in order to recover the most important properties of the distinct clouds separately. I am the PI for several HST/GHRS programs of this kind, and we have indeed found that the ground-based high-resolution data often play an invaluable role in the detailed interpretation of the lower resolution UV data from GHRS.

There is a second general way in which the ground-based data obtained under this grant can allow important improvements in typical analyses of UV interstellar lines measured with the GHRS. The accuracy with which the absolute wavelengths of interstellar lines, or the absolute radial velocities of interstellar clouds, can be measured with ground-based spectrographs at high resolution is very good: about $\pm 0.3 \text{ km s}^{-1}$. In contrast, zero-point errors of 5 km s^{-1} and 15 km s^{-1} , or more, are found quite commonly in default GHRS spectra recorded with the echelle and the first-order gratings, respectively. Knowing the absolute radial velocity of an observed cloud to an accuracy of perhaps $\pm 1 \text{ km s}^{-1}$ can be important in many scientific analyses, and a comparison with accurate ground-based line profiles is often the best (and sometimes the only) way of accurately calibrating the wavelength zero-point of a GHRS spectrum. One such method was used by Hobbs et al, ApJ, 411, 750 (1993) in calibrating their HST wavelength scales, for example.

It is accurate to say that this work has successfully pioneered the study of an important and previously unexplored regime. The continuity of the support I received for this work over some six years, by means of this (repeatedly peer-reviewed) grant, was vitally important. Only such sustained support would have permitted the consistent, focussed effort that has been required to obtain these particular results. Relatively long hours of observing time are necessarily required at the highest resolutions, to record the very finely subdivided starlight. I wish to express my sincere appreciation to the National Aeronautics and Space Administration for making this satisfying work possible.